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A 6 year climatology of fronts and their boundary layer structure in Helsinki

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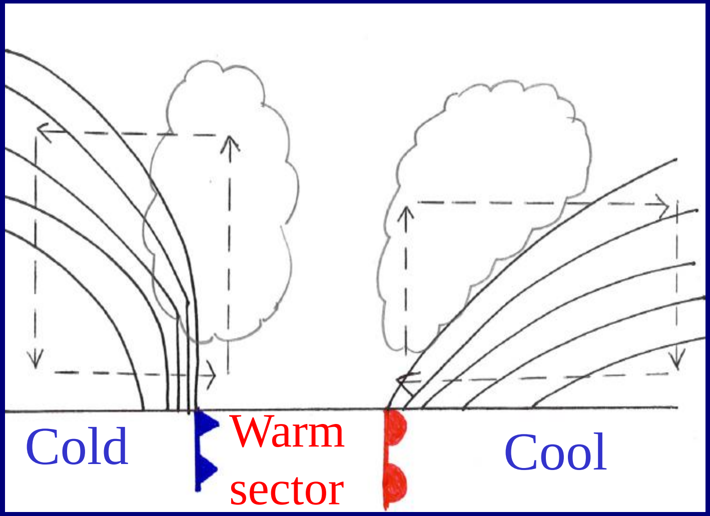
What are fronts and why construct a climatology of them?

- “the interface or transition zone between two air masses of different density.” AMS Glossary
- Surface fronts are analysed on the warm side of the thermal gradient



- Fronts are critical in determining the weather in mid-latitudes
- Fronts are sources of hazardous weather
- Fronts can transport pollutants
- Very few frontal climatologies exist
- Limited knowledge of the boundary layer structure of fronts
- Very limited knowledge of fronts at high latitudes or at the end of the storm track

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Questions to address

SYNOPTIC-SCALE

1. How often to warm, cold and occluded fronts affect Helsinki?
2. Do fronts affecting Helsinki exhibit a diurnal or seasonal cycle?

MESOSCALE / MICROSCALE

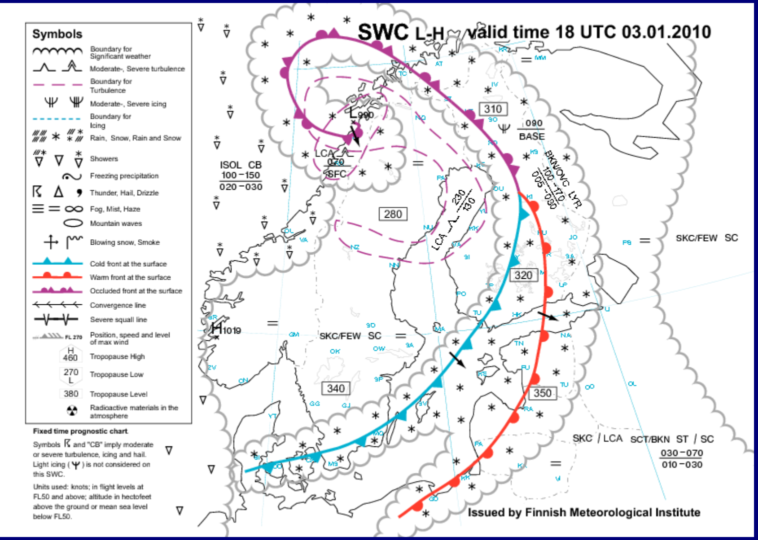
3. What is the average structure of a cold and warm front in Helsinki?
4. What factors influence the structure and characteristics of fronts?

Data Sources

1st Jan 2006 – 31st Dec 2011

Significant Weather Charts

Available every 6 hours from FMI



←Kivenlahti mast

7 temperature and 4 wind measurement levels between 5m and 327m

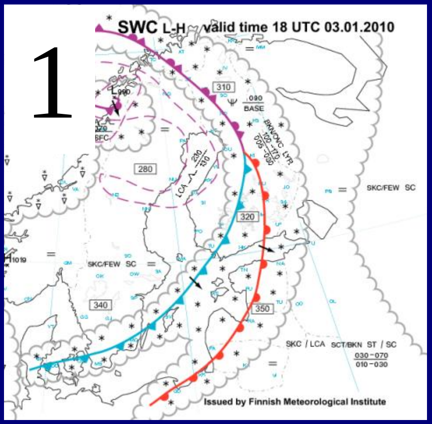
SMEAR III

Tower and roof measurements. Includes turbulent fluxes

SYNOPTIC SCALE → MESOSCALES → MICROSCALE

Method

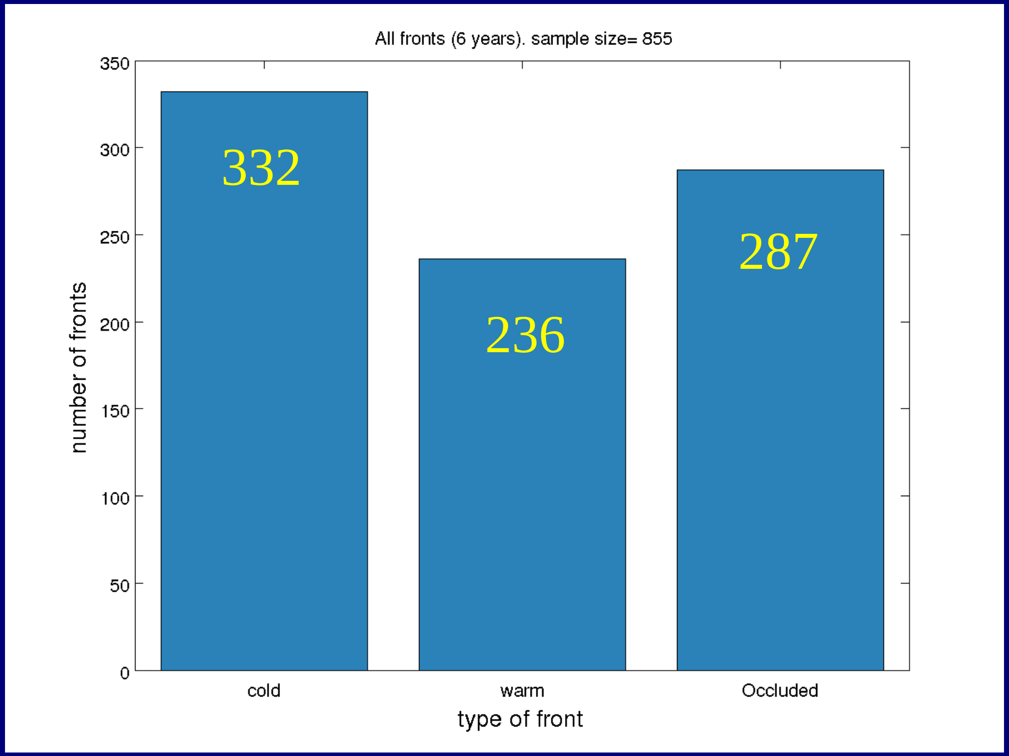
- **Part 1**. Manually analysis all SWCs for a 6 year period
  - Time, type, and direction of approach of all fronts
  - Fronts must be on 2 consecutive charts



- **Part 2.** Find analysed fronts in the tower observations.
  - The exact time of each front (start and end)
  - Temperature change
  - Wind direction change
  - Wind speed change
  - Lapse rate ahead of the front

- **Part 3**. SMEAR III observations
  - Assume fronts are observed at the tower and SMEAR III at the same time
  - Obtain precipitation, humidity and turbulent fluxes data for all fronts

Helsinki front climatology statistics



855 fronts were analysed

Cold front every 6.6 days

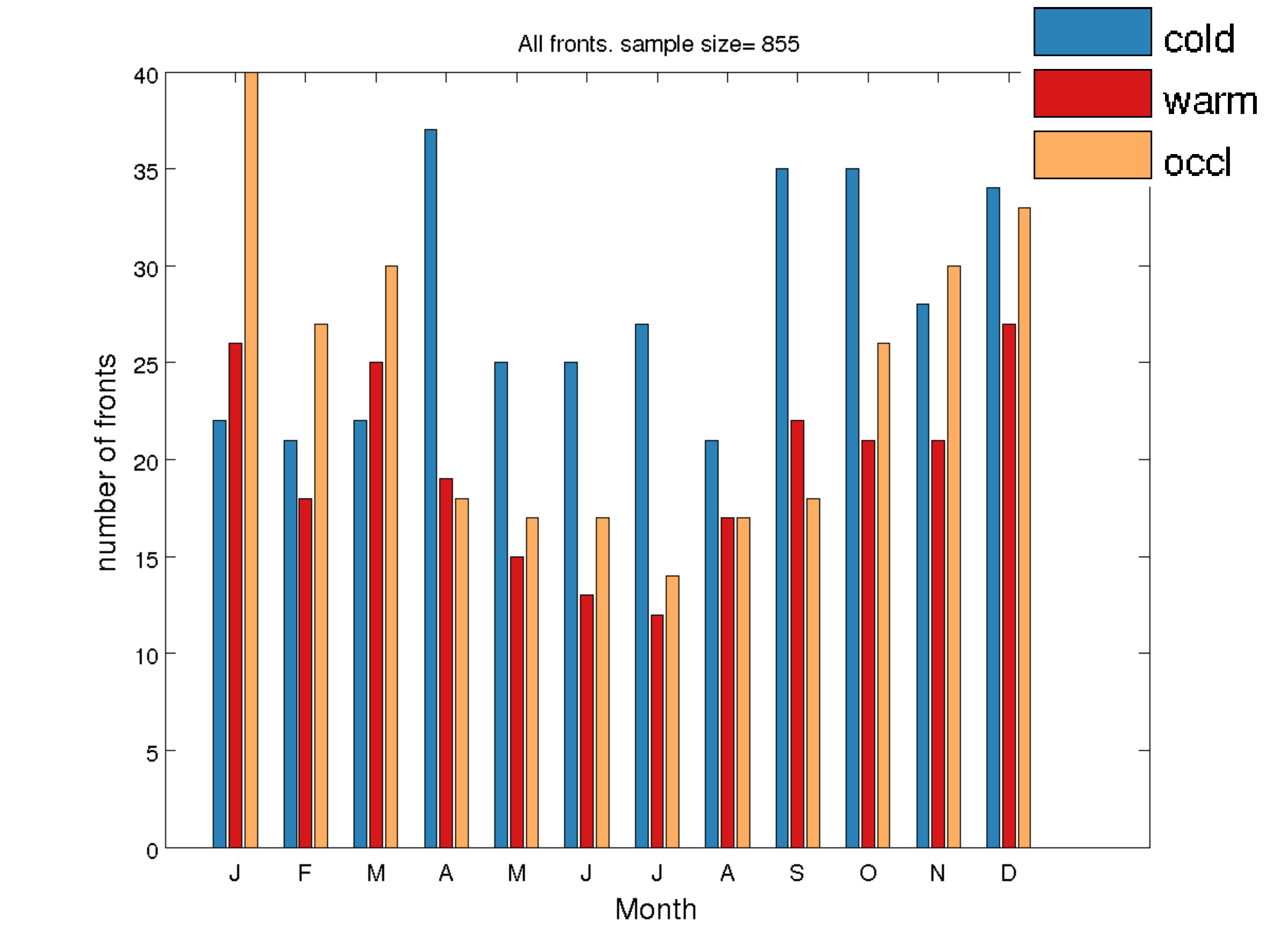
Occluded front every 7.6 days

Warm front every 9.3 days

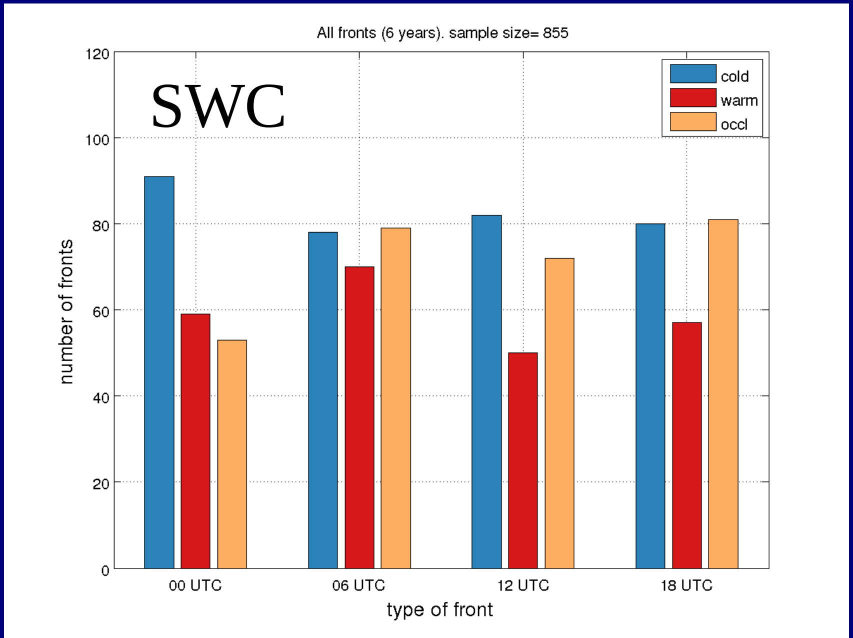
One front every 2.6 days

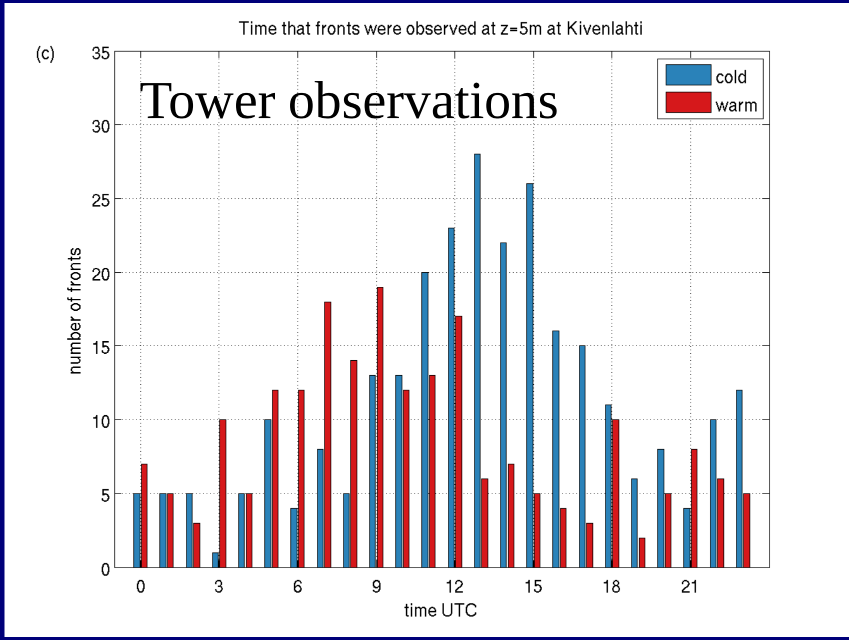
Cold fronts are the most common, then occluded fronts and warm fronts are the least common.

Seasonal cycle in frontal frequency



Diurnal cycle in frontal frequency

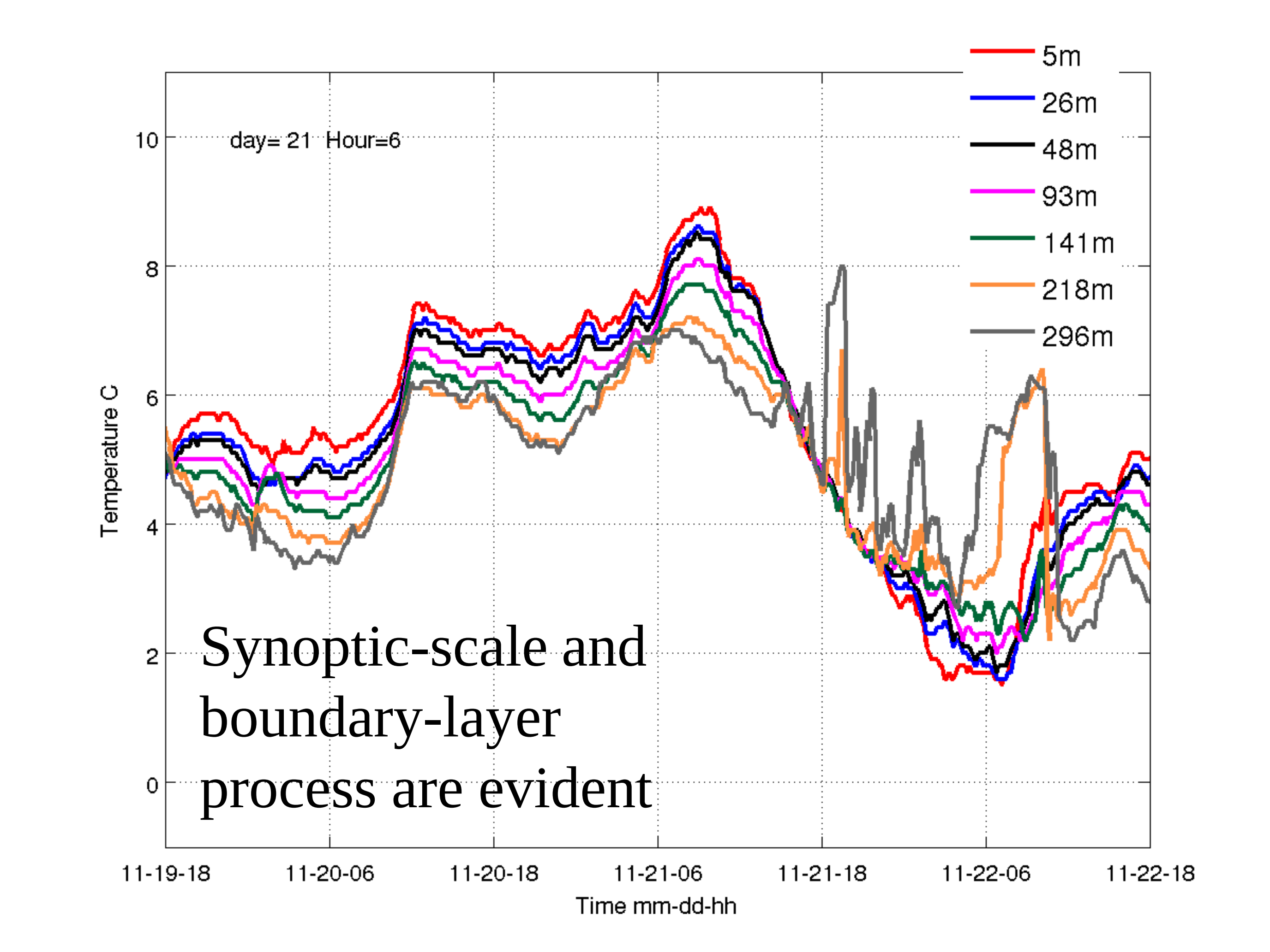




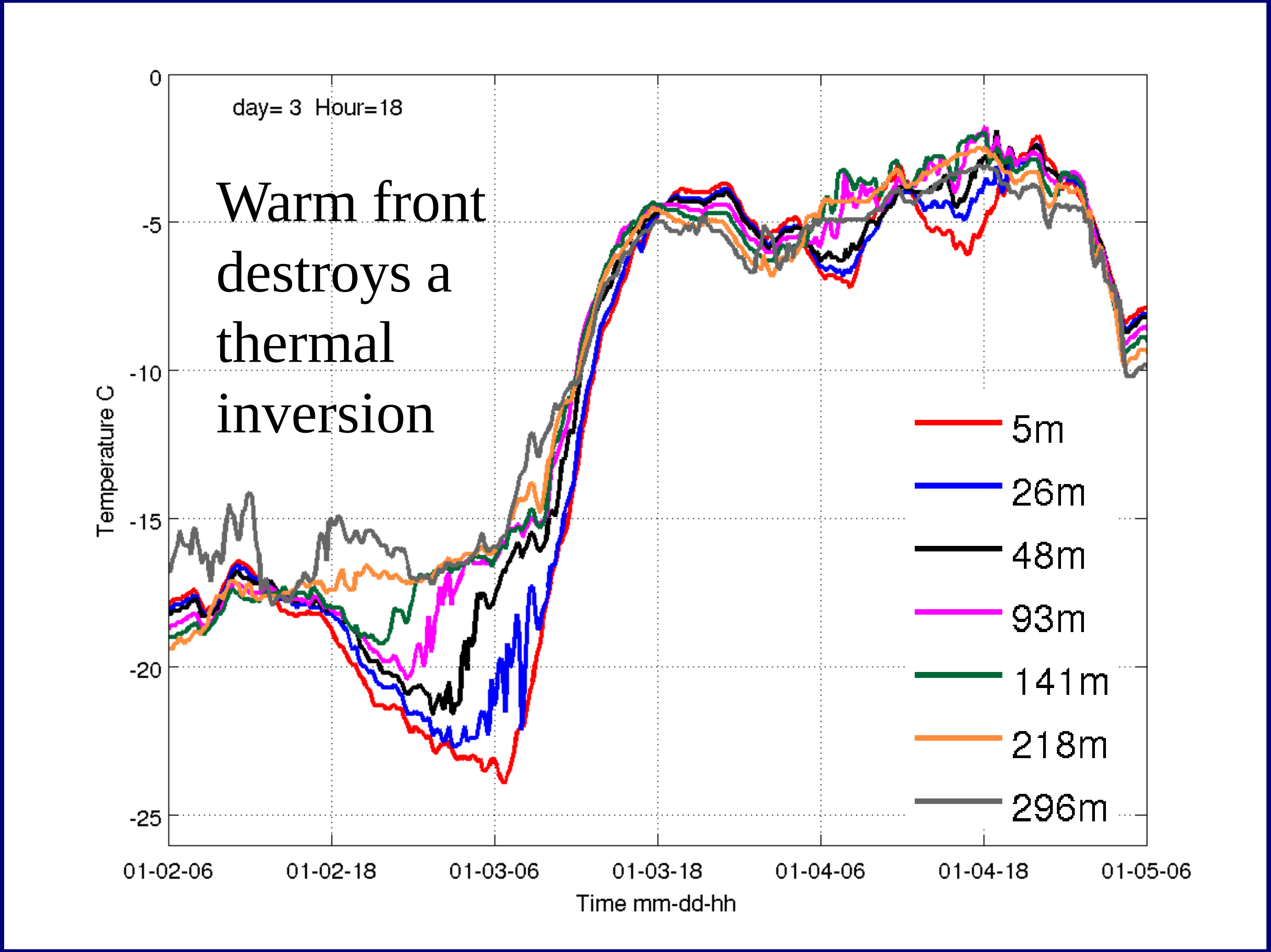
Only a weak diurnal cycle for warm fronts

Fronts are more common during the day than at night

Example of a warm and cold front

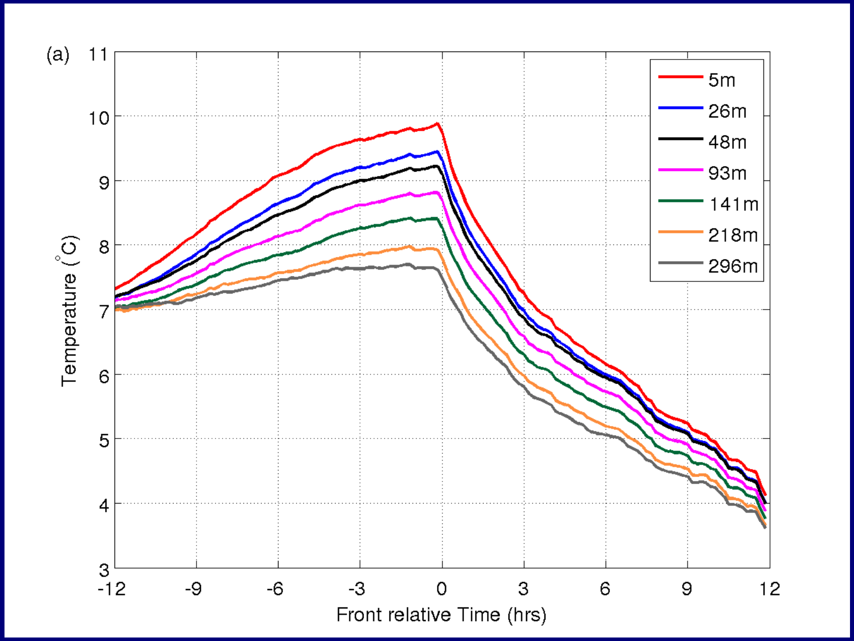


Example of a warm front



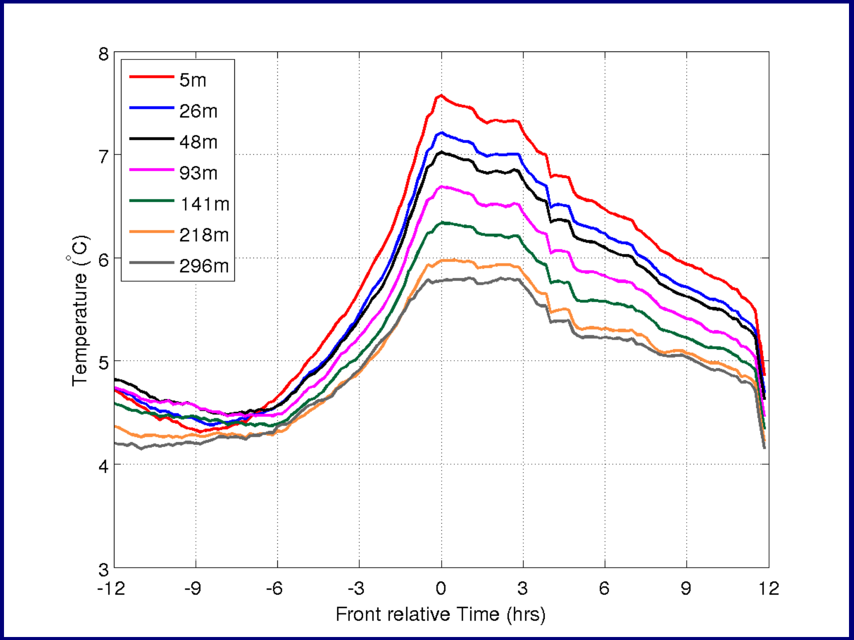
Composite fronts
Temperature timeseries

Average cold front



Average temperature change = -4.4C
Pre-frontal warming

Average warm front

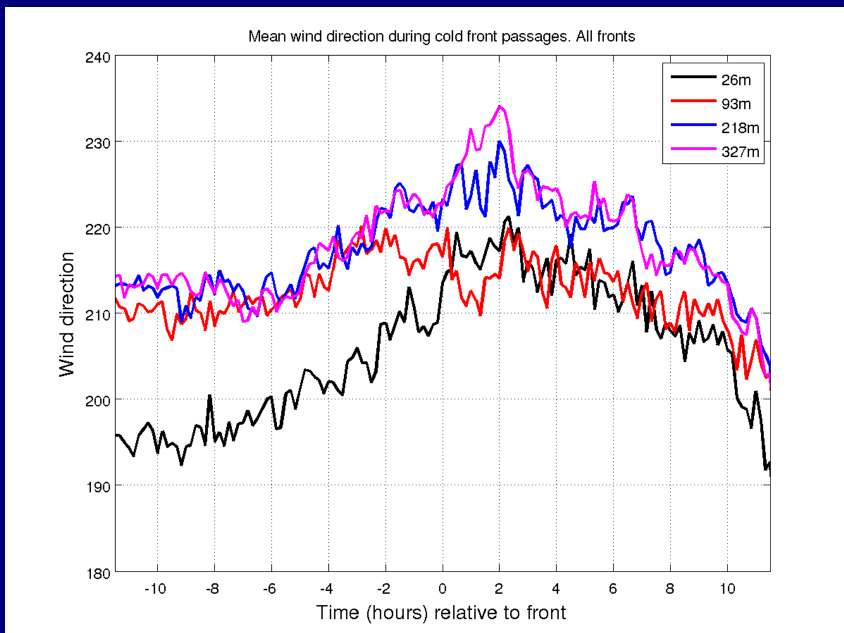


Average temperature change = +3.5C

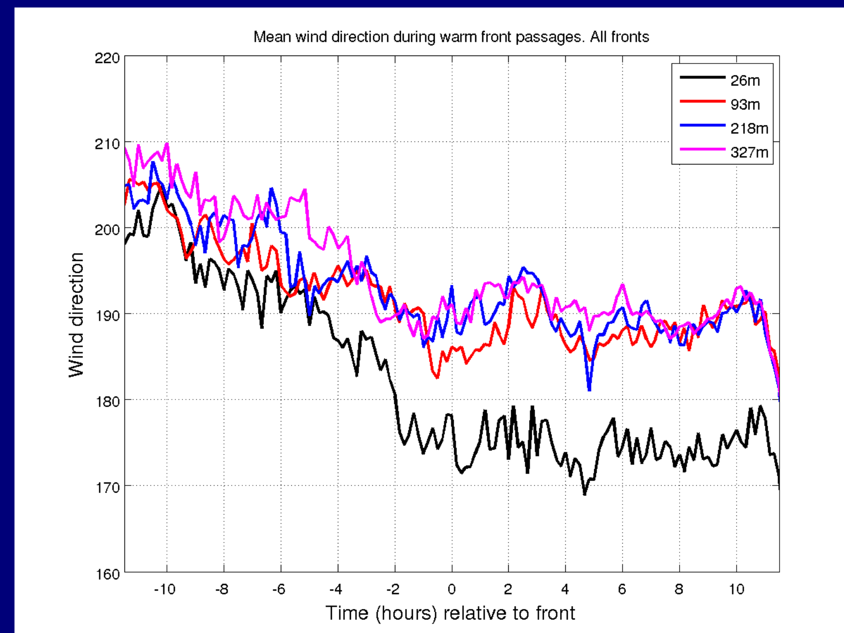
Temperature change is largest at the surface for warm and cold fronts

Composite fronts
Wind direction timeseries

Average cold front

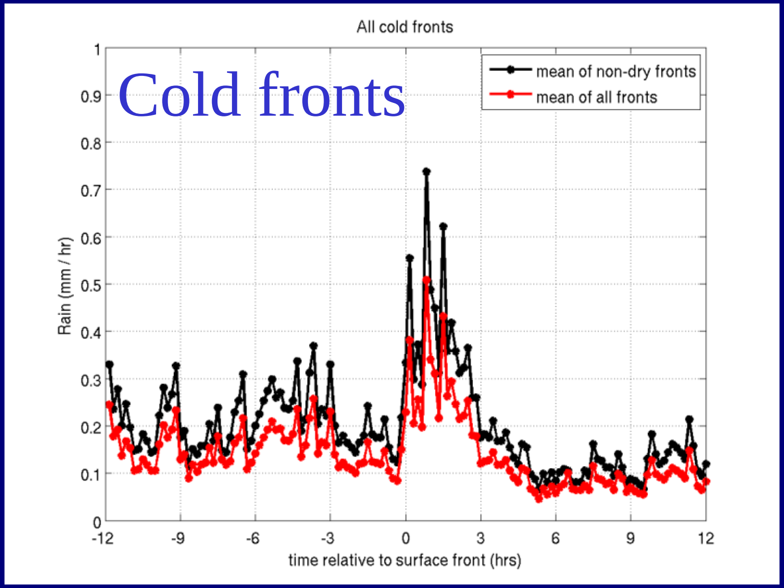


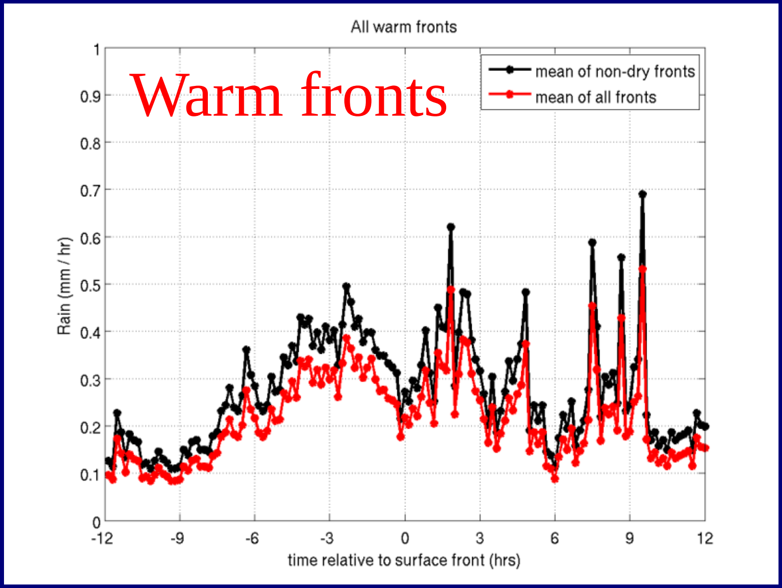
Average warm front



- Wind shift for both warm and cold fronts is about 20º
- Much noiser signal than temperature
    i. Turbulence
    ii. Not all fronts have a co-located wind-shift and temperature change

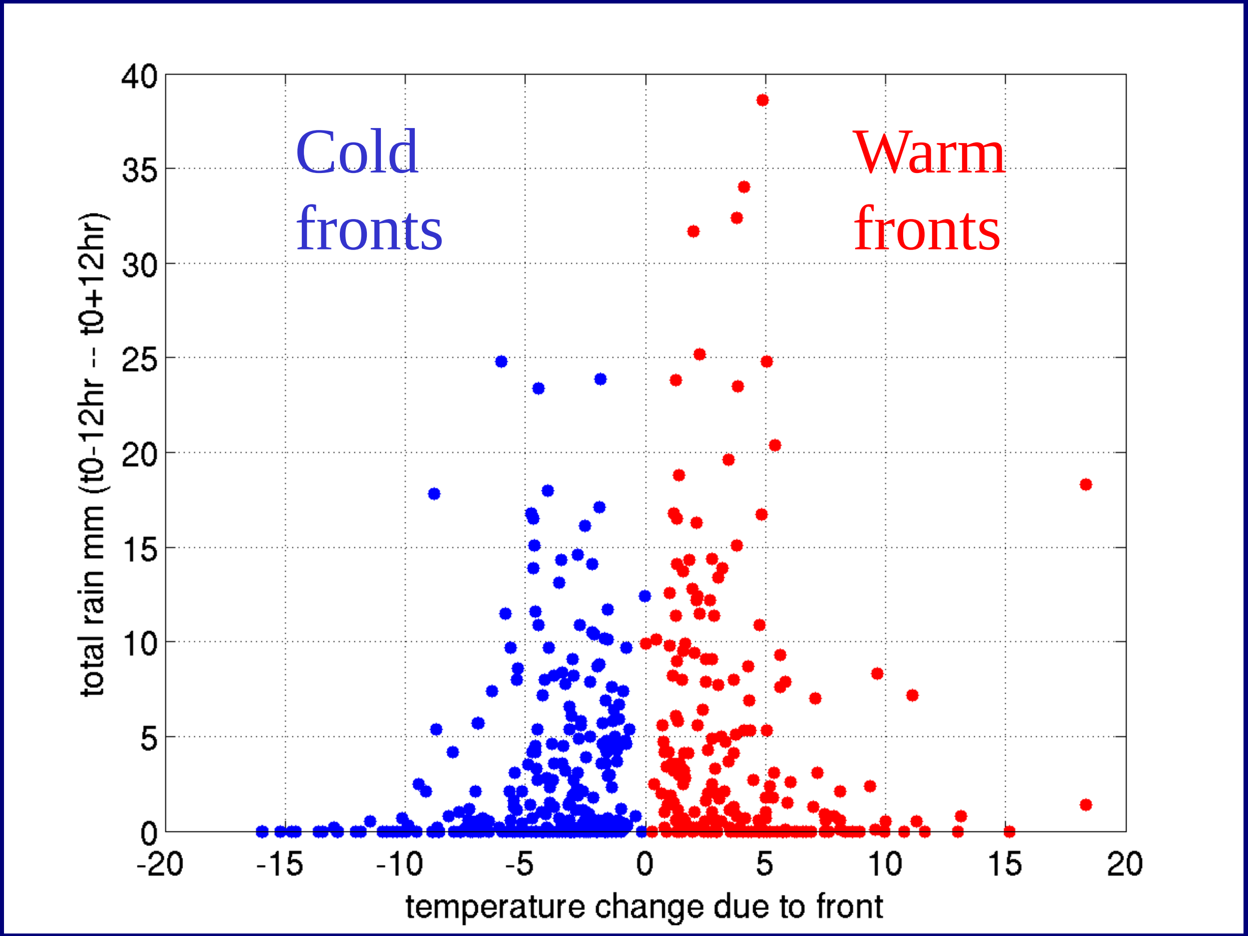
Composite front
Rain rates timeseries





- Cold fronts have most rain during the 3 hours after the front
- Warm fronts have large amounts of rain both ahead of and behind the surface front.
- Cold fronts produce heavier rain rates, but not more total rainfall

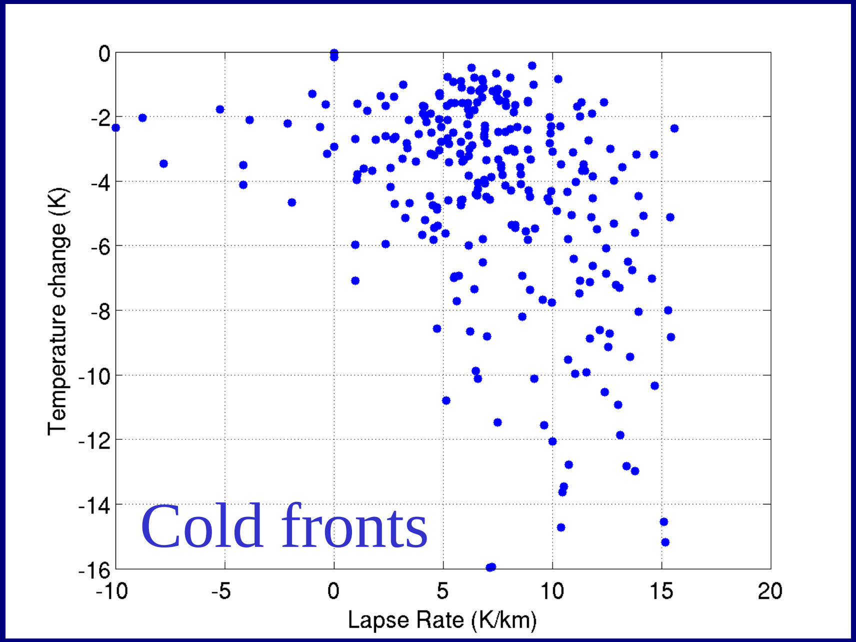
Precipitation as a function of temperature change

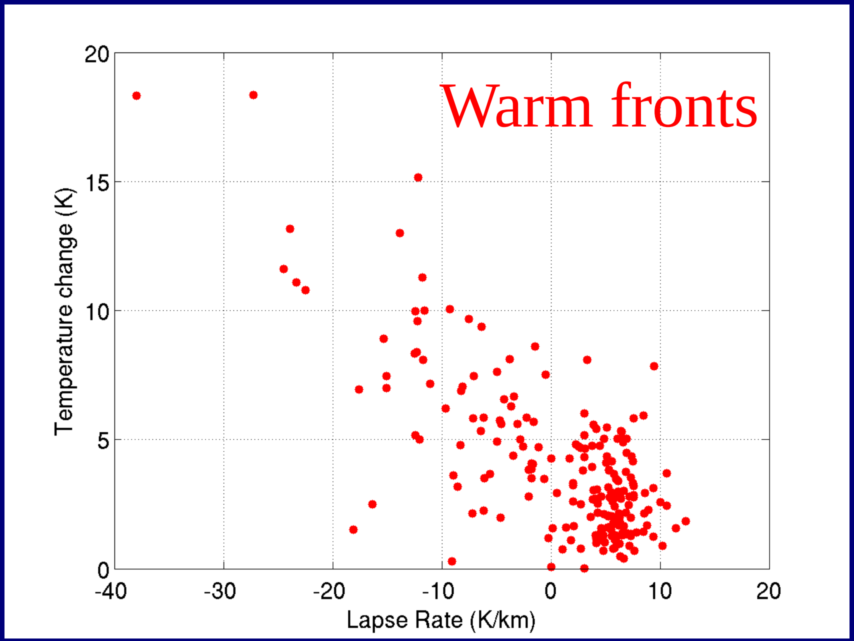


Fronts with smaller temperature changes produce more rain

Temperature change across fronts decreases as fronts begin to occlude

How does the low-level stratification ahead of the front affect the temperature change?





- The strongest cold fronts occur when the prefrontal BL is unstable
  - Positive heat fluxes ahead of front increase low level temperature → diabatic frontogenesis
- Strongest warm fronts occur when prefrontal BL is strongly stable
  - Negative heat fluxes ahead of the front → diabatic frontogenesis
  - Fronts can destroy inversions and mix warmer air down from above

Conclusions

- A front is observed in Helsinki every 2.6 days.
- Cold fronts are the most common
- Warm fronts are the least common
- Seasonal and diurnal cycles exist

- Frontal structures are determined by both synoptic-scale and boundary layer processess
- Composite fronts
  - reflect synoptic experience and conceptual models
  - quantify what is ”average”
- Large temperature changes ≠ lots of precipitation
- Temperature change is correlated with the stratification of the pre-frontal boundary layer

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